The NPARC Alliance: A New Way to Develop CFD

Jere J. Matty
Arnold Engineering Development Center
Arnold Air Force Base, TN 37389
and
Waldo A. Acosta
U.S. Army Research Laboratory
Lewis Research Center
Cleveland, OH 44135

July 13-16, 1998

ITEA 1998 Symposium
"High Performance Computing in Support
of Test and Evaluation"
Aberdeen, MD

The NPARC Alliance: A New Way to Develop CFD*

Jere J. Matty
Arnold Engineering Development Center
Arnold Air Force Base, TN 37389

Waldo A. Acosta
U.S. Army Research Laboratory
Lewis Research Center
Cleveland, OH 44135

Abstract

The Arnold Engineering Development Center (AEDC) and the NASA Lewis Research Center (LeRC) have formed an alliance aimed at developing, validating, and supporting a computational system called NPARC (National Project for Applications-oriented Research in CFD). The Alliance is supported by and responsive to an association made up of users from government, industry, and academic institutions. This paper provides an overview of the capabilities of the NPARC Alliance simulation system, a description of the development process, and discusses the history and progress of the Alliance to date.

Introduction

The NPARC Alliance began with an inlet computational fluid dynamics (CFD) peer review held at NASA LeRC in early 1992. At that time both Gerald Paynter from Boeing-Seattle and Ray Cosner from Boeing-St. Louis, then McDonnell Douglas, suggested that the goals of the Proteus code development and those of the PARC code were similar. This was followed by a chance meeting between two civil servants from AEDC and NASA LeRC at a government short course in March of 1992. The result was the creation of the NPARC Alliance. The NPARC Alliance draws on the unique talents and qualifications of its partners while at the same time soliciting the experience and insights of government, industrial, and academic users to ensure that code development proceeds in a cost-effective, customer-responsive manner.

There are many references available on the PARC and NPARC codes,[1-6] but in a nutshell, the NPARC Code is a general-purpose, Navier-Stokes code. It will handle inviscid or viscous, laminar or turbulent, steady-state or transient flows.

A major effort was undertaken last year to combine the capabilities of the NPARC code version 3.0, the NXAIR code used at AEDC for store separation, and the NASTD code in wide use at Boeing-St. Louis

---

* The research reported herein was performed by the Arnold Engineerring Development Center (AEDC), Air Force Materiel Command. Work and analysis for reseach were performed by personnel of United States Air Force; by personnel of Sverdrup Technology, Inc., AEDC Group, technical services contractor for AEDC; and by personnel of NASA Lewis Research Center. Further reproduction is authorized to satisfy needs of the U. S. Government.

into the WIND[7] code. The combined capabilities of these three codes was a major step forward towards meeting the needs of the users at all locations. Some of the features of the WIND code are:

- Improved Graphical User Interface
- Moving Grid Capability
- Improved/Expanded Documentation
- Emphasis on Portability/Maintainability
- Advanced Time-Accurate Solution Method
- Block and Chimera Interface

In FY98 the Alliance began working with the High Performance Computing Modernization Program, Common High Performance Computing Software Support Initiative (CHSSI) and the Air Force Research Lab (AFRL). Under the CHSSI program, the NPARC Alliance is working on improving the solver to exploit scalable computing systems. The focus of this paper will be the formation, organization, operation, and future of the NPARC Alliance itself.

Background

In the late 1970s a doctoral research effort at NASA Ames Research Center resulted in the development of the Ames Research Code (ARC). ARC was a general-purpose Navier-Stokes flow solver. In the mid-1980s AEDC acquired ARC and began tailoring the code for use as a production code for propulsion ground test and other related activities. This new code was called PARC. By the late 1980s, PARC had found wide usage throughout government, academia, and industry as a state-of-the-art, general-purpose, production code that had the added benefit of being available without charge. Each user treated the code as a local asset, and code improvements and documented uses were often not publicly shared. There was no established method of collecting and incorporating new code developments or noteworthy modifications into a central baseline code that was documented, supported, and validated. Figure 1 depicts a timeline of the events involved in PARC's development leading to the formation of the Alliance.

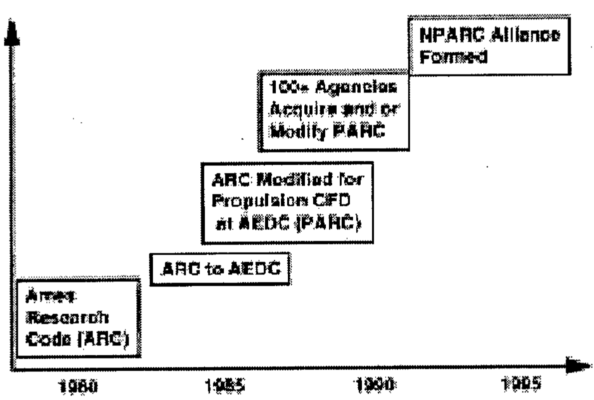

Figure 1. NPARC Origin

Two of the leading users and developers of PARC, AEDC and LeRC, began discussions in the early 1990s about the need to transition PARC from a local asset into a nationally useful, documented, supported, and validated CFD tool for commercial, academic, and government users. To formalize the alliance, a Memorandum of Understanding (MOU) was signed by the director of LeRC and the commander of AEDC in July of 1993. This MOU acknowledged that both centers worked in the development of complementary technologies and could each benefit from future cooperation. It was followed by an Annex to the MOU in September of 1993 that specifically addressed the NPARC Alliance. Since that time the NPARC Alliance has been used as a model for cooperation between the two centers, resulting in MOU Annexes and partnerships in the technical areas shown in Fig. 2.

The Alliance had to be formed with the understanding that the missions of NASA LeRC and AEDC are fundamentally different but complementary in nature.

The mission of the Lewis Research Center is:

To work as a team to develop and transfer critical technologies to aerospace and non-aerospace industries, universities, and government institutions. To fulfill this mission, the Center is committed to maximizing the return on the taxpayers' investment, to improving management and business practices, and to striving for diversity and value in the work force.

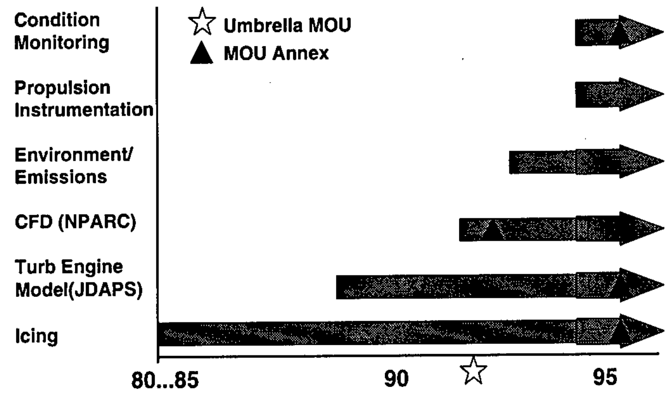

Figure 2. LeRC/AEDC Alliances

The mission of Arnold Engineering Development Center is:

To provide the world's most effective and affordable aerospace ground test products and services to our customers. To ensure ground test facilities, technologies, and knowledge are viable for today's and tomorrow's customers.

Although the two center missions are different, their accomplishment has grown to depend more and more upon the use of state-of-the-art CFD. The two centers were also experiencing budget cuts which encouraged collaboration on technology development efforts. Since no existing codes could be found to meet the needs of the two centers, development efforts have been underway at each facility for several years.

The purpose of the Alliance is consistent with the missions of the two centers and is captured in the following Vision and Mission statements:

Vision
The Computational Tool of Choice for Aerospace Flow Simulation

Mission
Develop, validate, and support an integrated, general-purpose, computational flow simulator for the US aerospace community. Collaborate with users to ensure that this simulation capability is the system of choice in the analysis, design, and development of aerospace vehicles and components.

The Vision and Mission statements are used to balance the near- and far-term goals of the Alliance. We have found it key to the health of the Alliance to keep a clear focus on our goals as put forth in these statements.

Organization/Operation

In order to achieve the vision and support the mission, the Alliance was structured to take advantage of each agency's strengths and abilities (Fig. 3).

The Executive Steering Committee consists of one manager from each Alliance partner (AEDC and LeRC). The Technical Liaisons lead the technical efforts at the two centers, supported by the Technical Direction Committee. This Committee is made up of one technical representative from each center in the three functional areas of the alliance: support, development, and validation.

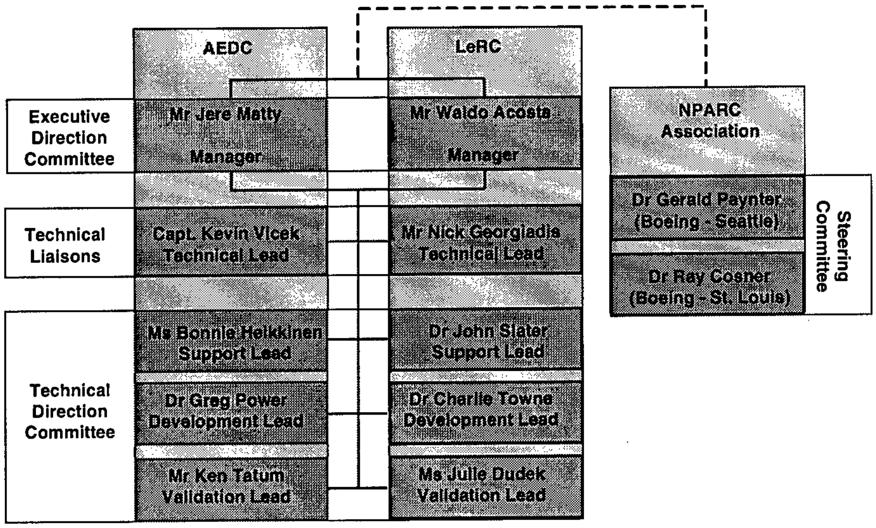

Figure 3. NPARC Alliance Organization

The NPARC Association is a self-governing group consisting of government, industry, and academic users. Any NPARC user who signs an NPARC Software Release Form (available in the Policies and Plans of the NPARC Alliance)[8] becomes a registered NPARC user and is eligible to be an Association member. A Steering Committee drawn from the NPARC Association is chartered by the Alliance to formalize users' inputs and provide feedback to the Alliance regarding current and future code developments. The current Association Steering Committee is co-chaired by representatives from the Boeing-Seattle and Boeing-St. Louis. The NPARC Association plays a key role in providing user community feedback to the Alliance to ensure NPARC remains useable, current, and relevant.

The alliance structure is designed to facilitate participation by all members and to make use of their unique talents. For example, this organization takes advantage of the fact that LeRC is strong in the areas of code development and validation and has made tremendous contributions to the code's turbulence modeling capabilities. AEDC is strong in areas of development and support and responsible for much of the user-friendly nature of the code. Our industry representatives are strong in each of these three areas. One key to the success of the Alliance to date has been the understanding that the cultures at AEDC, LeRC, and industry are very different. Although this can be frustrating at times, the team members have learned, and continue to learn, to value the differences. In other words, we are learning to take advantage of the fact that due to the differences in organizational mission, layout, mode of operation, educational background, and even geographical locations, we rarely see issues in a similar manner, yet we are all working towards a common vision and mission. The result has been that when the Alliance is presented with a challenge, we are able to come up with a much wider range of solution options than would normally be the case.

The second key to the Alliance is communication. This communication falls in two major areas, those internal and external to the Alliance.

A primary method for internal communication is the Annual Plans and Policy Document mentioned above. This document outlines the current Vision and Mission statements, as well as the current organizational structure. It also provides the forms required to obtain a copy of the code from the Alliance. However, the real meat of the document is the schedules for each of the three areas: development, validation, and support. These schedules are negotiated each year and define the expectations from each of the Alliance partners for the upcoming two years. An example of the validation schedule is shown in Fig. 4.

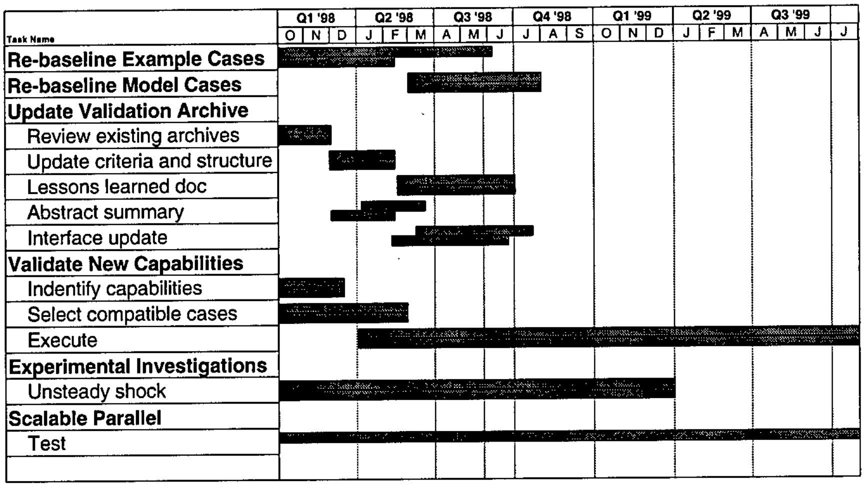

Figure 4. Plans and Policy Schedule

The Alliance has made extensive use of the video teleconference facilities at both centers. On roughly a monthly basis, we meet in "two dimensions" with the principal players from each center and "pipe in" AFRL and our key industry representatives from Boeing; i.e., they are connected by audio only. A key item on the agenda at these meetings is the review of progress on the three schedules in the current year's plans and policy document. Any business related to the Alliance is also discussed in these meetings to include issues both technical and managerial in nature. We also have frequent trips to the two centers and occasional trips to the Boeing facilities. One of the key internal communication methods has become the annual NPARC Workshop. The first of these took place at the Sheraton Hotel at the Cleveland airport, but subsequent workshops have been held at the Gossick Leadership Center (GLC) located at AEDC.

The GLC is a unique facility designed to host planning sessions often based on the Scan, Focus, Act model. In this model, the participants scan the environment for changes that will affect mission accomplishment, focus on what they can actually do to take advantage of the new situations, then schedule specific actions to deal with them.

Alliance Results

The results of these workshops are the draft for the next year's Policy and Plans Document. This document is finalized following the workshop and presented at the NPARC Users Meeting held in conjunction with the annual AIAA Aerospace Sciences meeting. This meeting is a key part of our external communications.

External communications follow multiple paths. The semiannual newsletters, alternately titled *The Predictor* and *The Corrector*, distribute Alliance news of interest to all users and stakeholders. There have been eight to date. We also sponsor NPARC Technical Sessions at conferences to include three sessions at the AIAA/SAE/ASME/ASEE Joint Propulsion Conference and four sessions at the AIAA Aerospace Sciences Conference and Exhibit. We have also sponsored an NPARC Session at the Applied Aero Conference. At each of these conferences we hold NPARC Users Meetings to keep our users aware of our status in the three areas of development, validation, and support, as well as solicit feedback. Eleven user's meetings have been held to date.

User surveys are also used to solicit user input to the Alliance. Two were conducted by mail and the third is now underway electronically via our NPARC Web Site (http://info.arnold.af.mil/nparc/ index.html). Figure 5 presents results of the electronic survey.

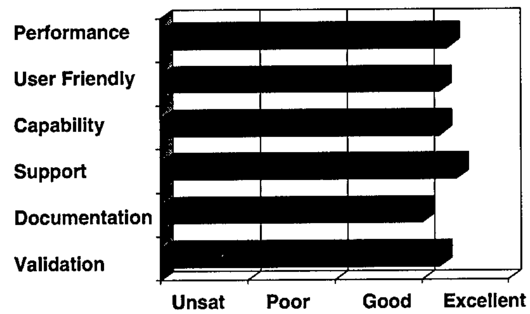

Figure 5. User Survey Results

The web site has been a key to external communication and contains the Alliance Vision/Mission statements, description of the flow simulator, the forms required to acquire the code, all documentation to include the user's guide in hypertext format, and application summaries (Fig. 6).

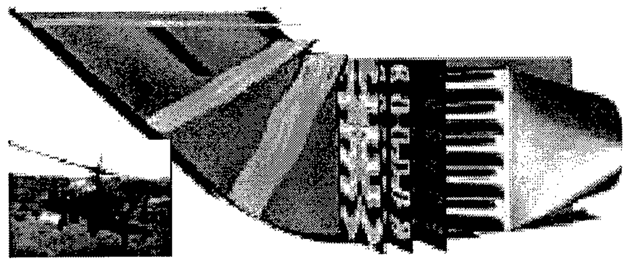
Figure 6. Solution from Applications Summary

The Validation Archives that covers all code validation activities are also available on the web site. Also available is The NPARC Technical Report Server (TRS). The TRS is a searchable database of technical papers dealing with the application, development, and validation of the code. A hot news section of the site is maintained to distribute bug fixes and 'hot' information. Also available are the Alliance Newsletters and a User's Bulletin Board. The bulletin board is used to communicate with the developers of NPARC or other users of the code. Finally, links are provided to pre- and post-processor tools for use with the solver. Communication statistics are gathered by the support team and displayed at the monthly VTCs (Fig. 7).

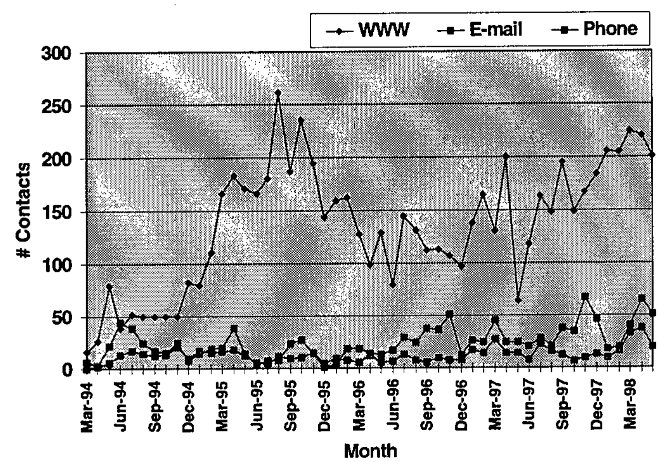

Figure 7. NPARC Communication Statistics

The support team also maintains a database of those requesting the code and their organizations (Fig. 8).

To date, over 700 requests for the code have been processed representing over 300 different organizations. The users represent all three branches of military service and every major aerospace firm. A wide range of universities are also represented. The Alliance is structured such that any improvements to the code made by a user can be submitted for inclusion in the official version- controlled code. This is not uncommon and has resulted in seven major releases of the code since the start of the Alliance.

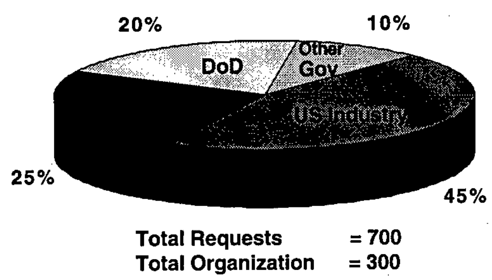

Figure 8. Code Request Statistics

Challenges

So far we have failed to discuss many of the challenges faced by the Alliance in getting to where we are today. They include:

- Yearly funding issues at each of the participants organizations
- Division of responsibilities in the Plans and Policy Document
- Deciding how much of the CFD problem to tackle, i.e., solver only or CADCAM to engineering units
- Integration with CFD work going on at other NASA and DoD centers
- Incorporation of more advanced technology (like unstructured gridding)

Even settling on the definition of the Alliance acronym (NPARC) and a name for the present solver (WIND) were not trivial tasks! But we have been successful to date due to the tremendous efforts of all the Alliance members who have come to realize that we are more productive as a team than we ever could be alone.

Future Plans

Our plans for the future are set at our annual workshop. Each year the Alliance seems to find itself at a crossroad, reshaping its structure and refining its path. This year was no different. Expanding the Alliance through the participation of other government and industry members was a major theme this year, as was moving to a modular framework to take advantage of new technologies. A team has been set up to explore these possibilities to strengthen the Alliance for the future.

Summary

The development and application of CFD has become a key to the success of the NASA LeRC, AEDC, and aerospace industry. The NPARC Alliance has been successful to date in leveraging the capabilities of both government and industry. The keys to its success include overcoming fears of working with people from different company cultures and backgrounds. The Alliance members have learned to value the differences and focus on a well-defined mission statement and organizational structure to get things done. Detailed plans and realistic schedules tie the responsibilities to specific efforts to be accomplished in fulfilling the mission.

No alliance could function properly without effective communication, and the NPARC Alliance has a thorough communication network, both formal and informal, at multiple levels. The formation of the NPARC Association and its interface to the Alliance are critical to maintaining a useable code containing the state-of-the-art features that the users deem important. Open communication forums like the Users' Association Meetings, the World Wide Web Home Page, and Internet e-mail help maintain timely and accurate collection and dissemination of current news and code status.

The result has been an organization that develops, validates, and supports a code that has found wide application throughout government, industry, and academia. Current plans for expanding the Alliance through the participation of other government and industry members, moving to a modular framework, and taking advantage of new technologies should further increase its effectiveness in solving the increasingly complex problems presented by the present times.

Additional Information

The Policies and Plans of the NPARC Alliance is a publicly available document that summarizes the philosophy and organization of the NPARC Alliance.[8] It also addresses the guiding policies for the support, development, and validation technical efforts in separate sections. Included in the policies are program plans and schedules addressing the activities planned within each technical area. These plans are continuously reviewed and formally updated annually to reflect the current goals and directions of the Alliance. The program plans also indicate which Alliance partner is responsible for which activities. The document also includes instructions for obtaining NPARC Alliance Codes and a copy of the Proprietary Protection Agreement.

Further information on the NPARC Alliance is also available through the World Wide Web at //http:info.arnold.af.mil/nparc, or by e-mailing a request for information to nparc-support@info.arnold.af.mil.

References

1. Burns, J. E. and Smith, C. F., "Installed F/A- 18 Inlet Flow Calculations at a High Angle of Attack," *Journal of Propulsion and Power*, Vol. 10, No. 1, January and February, 1994, pp. 110-115.

2. Chaing, I. and Hunter, L. G., "Over-Under Nozzle CFD Study and Comparison with Data," AIAA-94-2949, AIAA/ASME/SAE/ASEE 30th Joint Propulsion Conference, Indianapolis, IN, June 27- 29, 1994.

3. Georgiadis, N. J., Drummond, J. E., and Leonard, B. P., "Evaluation of Turbulence Models in the PARC Code for Transonic Diffuser Flows," AIAA-94-0582, AIAA 32nd Aerospace Sciences Meeting and Exhibit, Reno, NV, January 10-13, 1994.

4. Mayer, D. W. and Paynter, G. C., "Boundary Conditions for Unsteady Supersonic Inlet Analyses," *AIAA Journal*, Vol. 32, No. 6, June 1994, pp. 1200-1206.

5. Power, G. D., McClure, M. D., and Vinh, D., "Advanced IR Suppressor Design Using a Combined CFD/Test Approach," AIAA-94-3215, AIAA/ ASME/SAE/ASEE 30th Joint Propulsion Conference, Indianapolis, IN, June 27-29, 1994.

6. Cooper, G. K. and Sirbaugh, J. R., "The PARC Distinction: A Practical Flow Simulator," AIAA-90-2002, AIAA/ASME/SAE/ASEE 26th Joint Propulsion Conference, Orlando, FL, July 16-18, 1990.

7. Bush, R. H., Power, G. D., and Towne, C. E., "WIND: The Production Flow Solver of the NPARC Alliance," AIAA 98-0935, AIAA 36th Aerospace Sciences Meeting and Exhibit, Reno, NV, January 12-15, 1998.

8. "Policies and Plans of the NPARC Alliance." Arnold Engineering Development Center, August 1997.